

PARALLAX NAMES AND DATES

Pythagoras of Samos	575 – 495 BC
Aristotle of Macedonia	384 – 322 BC
Euclid of Alexandria	325 – 265 BC
Aristarchus of Samos	310 – 230 BC
Eratosthenes of Cyrene	276 – 194 BC
Hipparchus of Nicaea	190 – 120 BC
Ptolemy of Thebaid (Egypt)	85 – 166 AD
Johannes Kepler (Germany)	1571 – 1630
Isaac Newton (England)	1643 – 1727
Christian Huygens (Holland)	1629 – 1695
Edmond Halley (England)	1656 – 1742
Friedrich Bessel (Westphalia)	1784 – 1846

ARISTARCHUS.

Heliocentric model. Sun is at least 19 times bigger (and further) than the moon (actually 390 times). Size of earth's shadow relative to the moon – the earth is 2.85 times bigger than the moon (actually 3.67; the main error is due to the cone). Logic: the sun is biggest, hence it is in the center.

ERATOSTHENES.

Calculated the earth circumference (around 240 BC) : sun elevation in Alexandria at noon on June 21 is $7^{\circ}12'$ off vertical, sun elevation in Syene is vertical, distance=5000 stadia (?); hence 1/50 of the earth circumference is 5000 stadia. Calculated the tilt of the earth axis.

HIPPARCHUS.

Greatest astronomer of antiquity. Farther of geocentrism. "On sizes and distances [of the earth and the moon]" (reported by Pappas and Ptolemy in Almagest).

1. Lunar eclipse (duration, 270 BC): r - earth radius, $2r$ - shadow cylinder, t - time it takes the moon to cross the shadow (approx. 3 hours), T - moon period (29 days), R - distance to the moon; proportion $T \sim 2\pi R$, $t \sim 2r$, hence $R/r = T/(\pi t) = 60$; main mistake: the earth shadow is a cone.
 2. A parallax measurement of the distance to the moon using a solar eclipse: the distance between Alexandria and Helleport (the Dardanelles) is 1000 km (perpendicular distance 700 km), the eclipse is total in Helleport and $4/5$ (0.1°) in Alexandria; hence $R = 700 / (0.1^{\circ}\pi/180^{\circ})$ km (62-73 earth radii).
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PTOLEMY.

Actual parallax measurement of the distance to the moon (59 earth radii). He compares (Almagest) the moon viewed from Alexandria to the moon viewed from the center of the earth. Inverse computation of solar parallax. Results: distance to the moon = 59 earth radii, diameter of the moon = 0.292 diameter of the earth (very precise, measured by lasers with corner reflectors on the moon); distance to the sun = 1210 earth radii, diameter of the sun = 5.5 diameter of the earth (wrong by a factor of 20).

ASTRONOMICAL UNIT AND TRANSITS OF VENUS

In 1716 Edmond Halley (discovered Halley's comet) proposed using transits of Venus to estimate the distance to the sun (AU). The idea is to measure the parallax of Venus relative to the sun and use the known ratio of the radii of the earth and Venus orbits. It was actually developed by James Gregory in 1663, but Halley neglected to mention this fact.

Past and future transits: 1631, 1639, 1761, 1769, 1874, 1882, 2004, 2012, 2117.

Could be the first example of large scale international scientific collaboration:

Cook (1769) traveled to the Pacific and discovered Australia. Astronomers went to distant places (Siberia, Madagascar, etc.) to have a longer base and to beat the weather collectively. In 1771, using the combined 1761 and 1769 transit data, the French astronomer Jérôme Lalande, calculated the astronomical unit to have a value of 153 million kilometers (± 1 million km).

STELLAR PARALLAX

Parallax second: 1 parsec = 3.26 ly (light years) = 3×10^{13} km; the distance at which the radius of the earth orbit is seen at an angle of 1". Alpha Centauri 4.37 ly, Proxima Centauri 4.23 ly = 1.3 pc, Sirius 8.6 ly = 2.6 pc.

Friedrich Bessel (1838) estimated the distance to 61 Cygni at approx. 3 pc (.314").

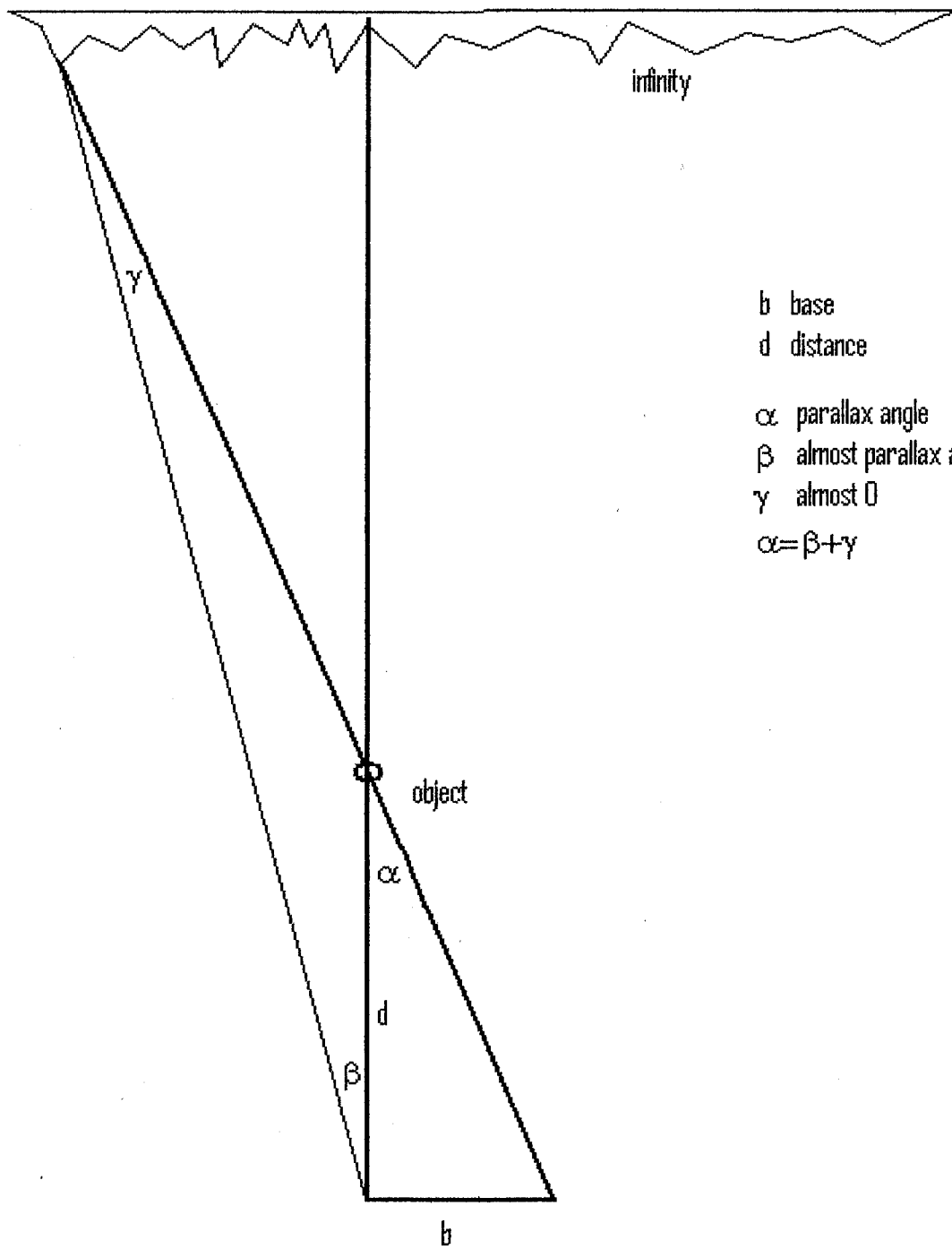
Stellar parallax is the first direct proof of the fact that the earth is in orbit around the sun. Good ground telescopes can measure distances up to 100 pc; the Hipparcus (space based) has measured distances up to 1000 pc. Milky Way diameter is approx. 30 kpc (100,000 ly). Distance to Andromeda is about 2.5 million ly.

COSMIC DISTANCE LADDER

Standard candle is a class of objects whose luminosity is known.

Cepheids (variable stars) change brightness; 3 days – 800 suns, 30 days – 10,000 suns.

Type Ia supernovae is 5 billion times brighter than the sun (a binary consisting of a white dwarf feeding on a red giant; the dwarf explodes exactly at 1.4 solar masses).



- b base
- d distance
- α parallax angle
- β almost parallax angle
- γ almost 0
- $\alpha = \beta + \gamma$