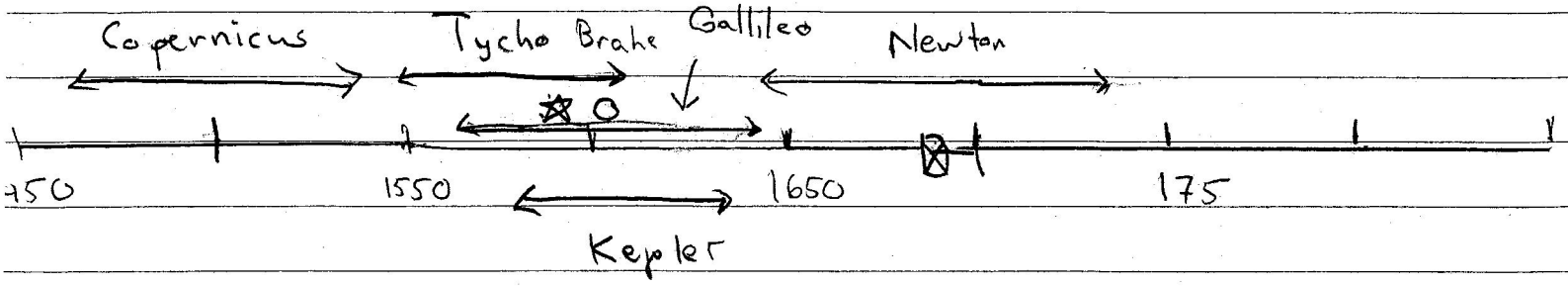
Timeline:



☆ - 1609 Astronomia Nova (Kepler's Laws)

○ - 1610 Invention of Telescope, Sidereus Nuncius (Jupiter's moons)

☒ - 1688 Newton's Principia (Venus Phase)

Philosophiae Naturalis
Principia Mathematica

Explains Kepler's Laws

(And just about everything else)

Tycho Brahe (1546-1601) / All with naked eye

- Eldest son of a noble family
- At thirteen saw a partial eclipse as predicted by Ptolemy's Almagest
- At seventeen witnessed Jupiter and Saturn passing close to each other
- Built a sextant capable of measuring ~ 2 Arc minutes / Astro
- Witnessed the Nova 1572 and determined that its position was fixed with respect to the stars

  - De Nova Stella

- Then famous and wanted to move to Basle Switzerland, to keep him in Denmark,
- King Fredrick II offered him a castle and ~ 40 farm + worker

Uraniborg - the first ever research

Notes about Tycho's instrument

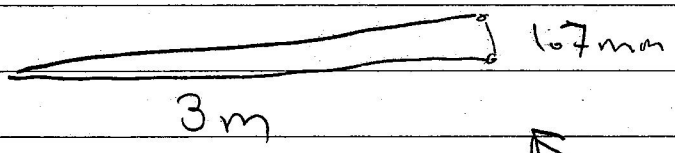
- Lets get a sense of what an 2r arc minutes means

$$1 \text{ arcmin} = \frac{1}{60} 1^\circ$$

So

$$2 \text{ arcmin} = \frac{2}{60} \times \frac{2\pi}{360} \text{ radians} = 0.00058$$

So if the distance to wall is 3m



This is just barely visible

With lots of visitors

→ Lots of parties / drinking

→ He boasted a dwarf (Jeph) ⓦ second sight

→ And a tame-elk who died one night falling down the stairs after drinking to much

- Through all this he recorded the positions of the planets and stars with incredible precision

→ each measurement was checked by four people

→ An incredible amount of data

Kepler (1571-1630)

- Believed in the Copernican System
  → Quote on Astrology
- But also tried to construct a geometric model of the planets

  Based on circumscribing circles with regular polyhedra (Mysterium Cosmographicum

  It Didn't work.

- Wanted to get a hold of Tyco's data on mars to test his theories

  → Quote on Tycho

- But Tycho was very secretive about his data.

  → He wanted to defend his own system not the Copernican one

- Eventually Tycho died and Kepler grabbed the data

Instead, Kepler was offered a professorship of astronomy in faraway Graz, Styria (now part of Austria), where he went in 1594. One of the duties of this professorship was to make astrological predictions. Despite his earlier efforts at horoscopes, he wrote "a mind accustomed to mathematical deduction, when confronted with the faulty foundations (of astrology) resists a long, long time, like an obstinate mule, until compelled by

beating and curses to put its foot into that dirty puddle" (ref 1, page 245). Nevertheless, he predicted a cold winter, and an invasion by the Turks. Both predictions turned out to be correct. He was treated with a new respect, and his salary was increased.

he had ever met Tycho, he wrote to his mentor Maestlin:

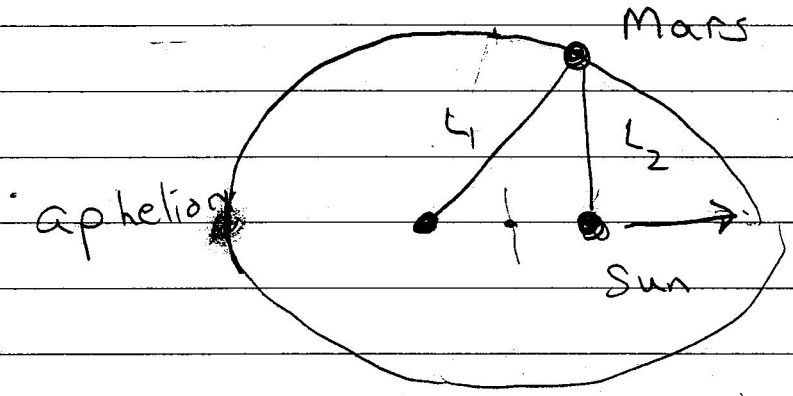
"*My opinion of Tycho is this: he is superlatively rich, but he knows not how to make proper use of it, as is the case with most rich people. Therefore, one must try to wrest his riches from him.*" (ref. 1, page 280)

later died in agony of a bladder infection. Tycho's heirs were anxious to make as much money as possible out of the estate, and the impoverished Kepler realized that if he didn't act immediately, he would never get to use most of Tycho's data. As he wrote in a letter in 1605: "*I confess that when Tycho died, I quickly took advantage of the absence, or lack of circumspection, of the heirs, by taking the observations under my care, or perhaps usurping them...*" (ref 1, page 280)

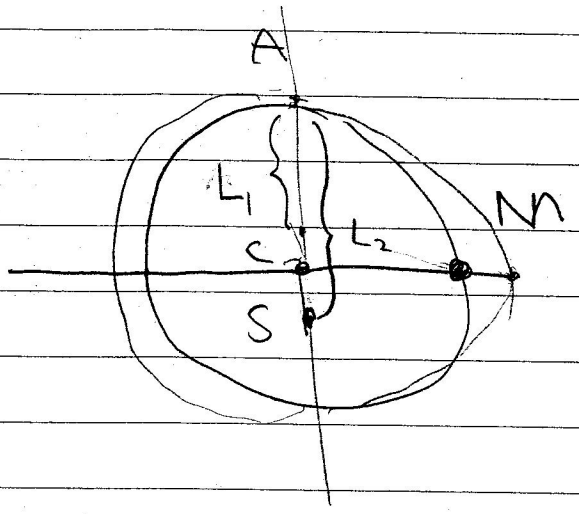
Kepler's Laws - From Observing Mars

I. The Planets move on Elliptical Orbits (But the ellipticity is small)

Ellipse Basics:



- $L_1 + L_2 = \text{Constant}$
- The sun is at one focus

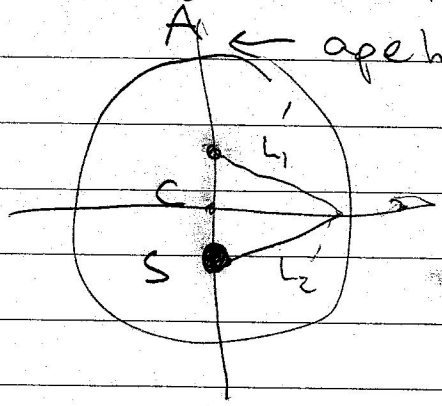


$CA = 1.00429\ mc$

So

$$L_1 + L_2 = 2CA = 2.00858\ mc$$

Then noticed that:



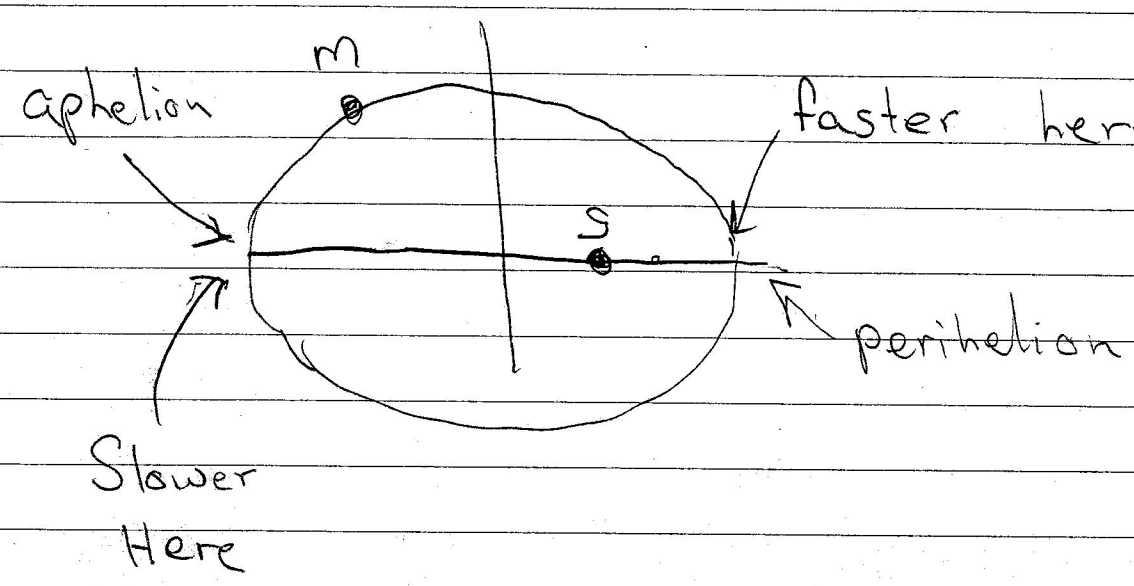
Is also

$$L_1' + L_2' = 2.00858\ mc \quad \text{Same!}$$

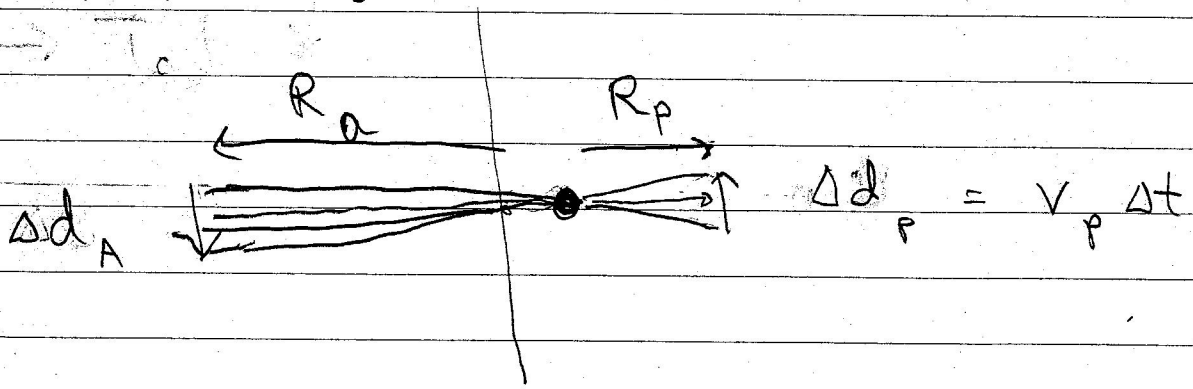
Thus notice that in fact

$L_1 + L_2$ is constant throughout the year

II. Then Kepler Noticed that the planets sweep out equal areas at equal times



In time Δt:



Find that in time Δd

$$R_a \Delta d_a = R_p \Delta d_p$$

large small small large

III. Kepler's -- Third Law

The square of the orbital period is proportional to cube of the average of the radii

$$a \equiv \frac{R_p + R_a}{2}$$

So

$$T^2 \propto a^3$$