MODERN PERIOD (FROM 1400 AD TO THE PRESENT DAY)

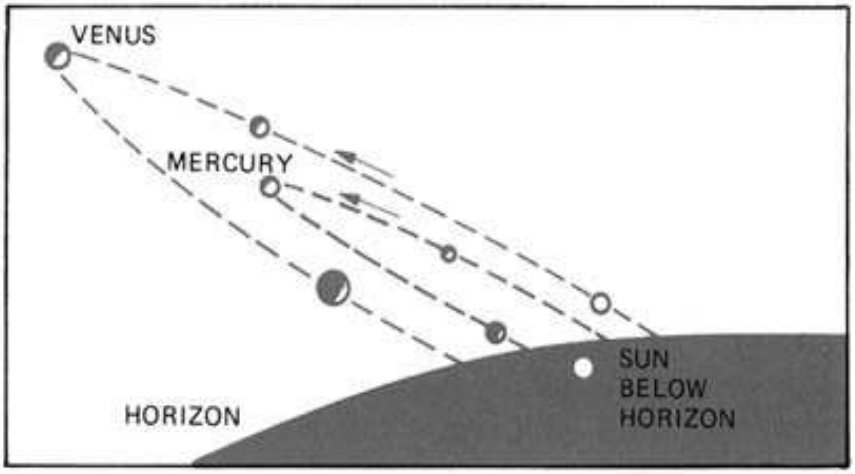
ASTRONOMY IN THE RENAISSANCE

THE COPERNICAN REVOLUTION

NICOLAUS COPERNICUS (1473–1543) REINTRODUCED THE HELIOCENTRIC MODEL: ALL PLANETS, INCLUDING EARTH, REVOLVE AROUND THE SUN IN CIRCULAR ORBITS WITH THE SUN AT THE CENTER.

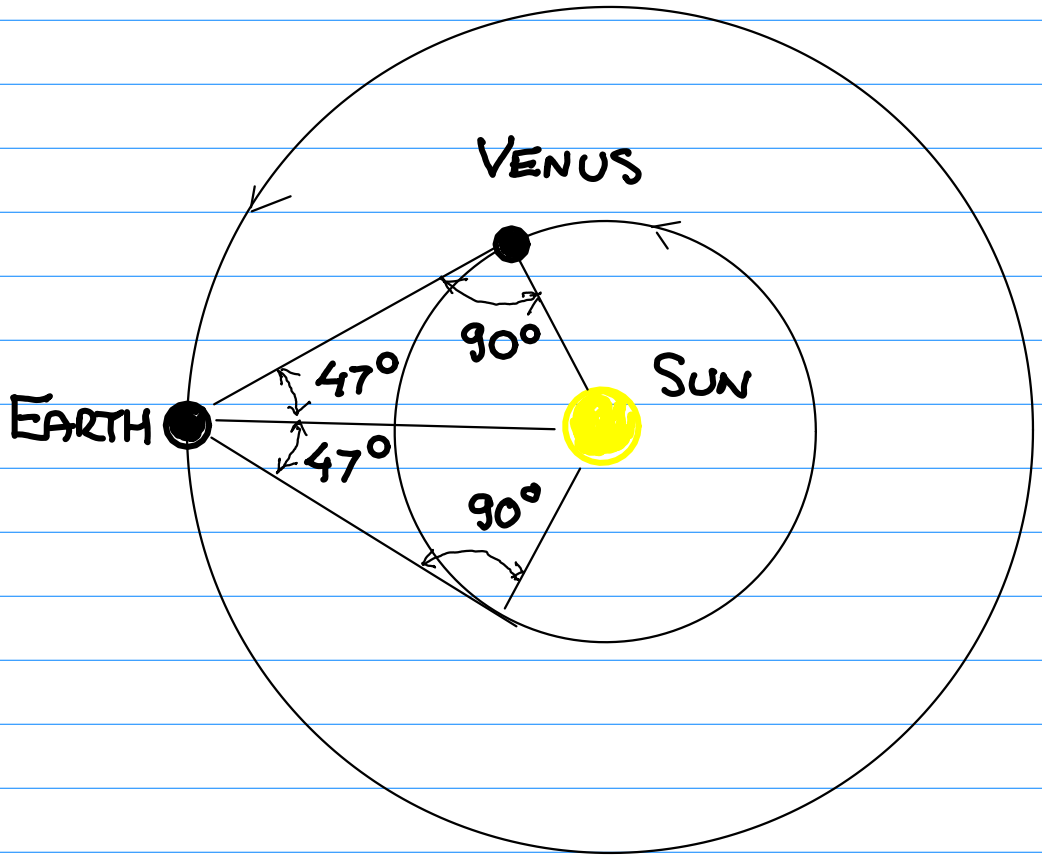
1) WITH HELIOCENTRIC HYPOTHESIS IT WAS POSSIBLE TO DETERMINE THE DISTANCES OF PLANETS FROM THE SUN IN THE UNITS OF EARTH-SUN DISTANCE (I.E. AU):

OBSERVATION:



THE MAXIMUM ALTITUDE OF VENUS IS 47°
THE MAXIMUM ALTITUDE OF MERCURY IS 28°

HELIOCENTRIC MODEL:



USE SIMILAR TRIANGLES (OR TRIGONOMETRY) TO FIND THE RATIO

$$\frac{\text{VENUS} - \text{SUN DISTANCE}}{\text{EARTH} - \text{SUN DISTANCE}}$$

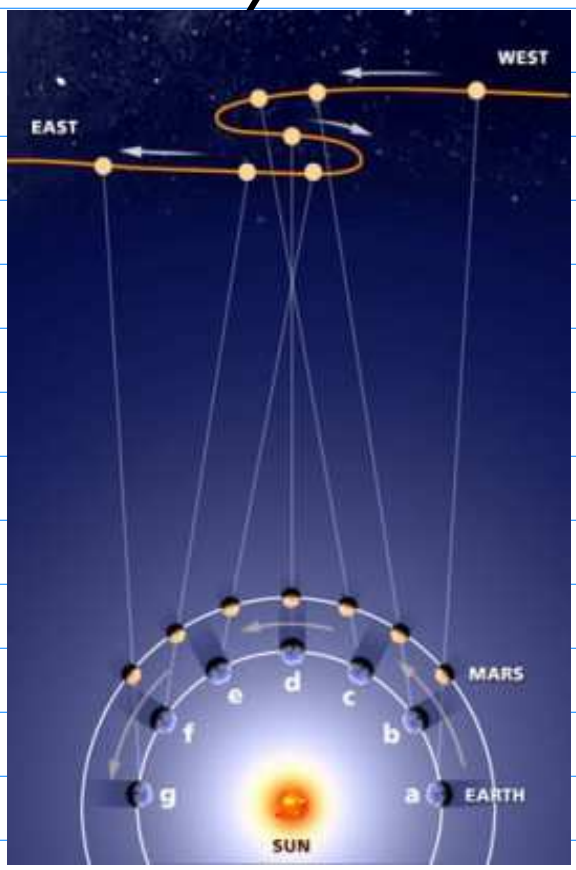
2) MEASURE THE ORBITAL PERIODS OF PLANETS AND THEN DEDUCE THEIR ORBITAL SPEEDS

$$v = \frac{2\pi \times \text{DISTANCE TO THE SUN}}{\text{ORBITAL PERIOD}}$$

IN THE UNITS OF EARTH'S ORBITAL SPEED.

FINDING: THE GREATER THE DISTANCE OF THE PLANET FROM THE SUN, THE LOWER IS ITS ORBITAL SPEED.

3) THEN THE RETROGRADE MOTION OF PLANETS AS OBSERVED FROM EARTH IS EXPLAINED IN A NATURAL WAY:



THE MAIN OBJECTION TO HELIOCENTRIC MODEL WAS STILL THAT THE STELLAR PARALLAX WAS NOT OBSERVED.

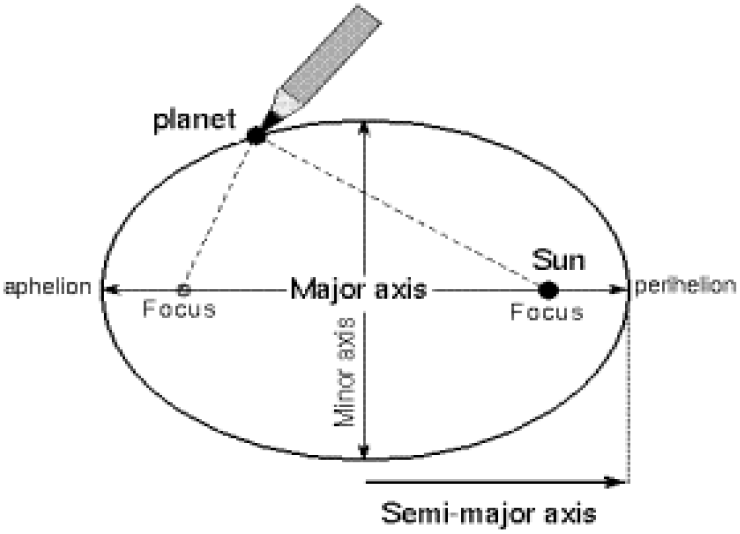
TYCHO BRAHE (1546-1601) WAS THE GREATEST NAKED-EYE OBSERVER IN THE HISTORY OF ASTRONOMY.

BRAHE USED MURAL QUADRANT TO MEASURE THE ALTITUDE ANGLES TO WITHIN $\frac{1}{2}$ MINUTE OF ARC (i.e $\frac{1}{2}\frac{1^\circ}{60}$).

HE REPEATED THE MEASUREMENTS SEVERAL TIMES AND AVERAGED THE RESULTS IN ORDER TO ELIMINATE RANDOM ERRORS.

In this way Brahe obtained very accurate data on the orbital motions of planets (Mars in particular).

Johannes Kepler (1571–1630) worked on Brahe's data on planetary orbits for 8 years and established 3 empirical laws which govern the motions of the planets

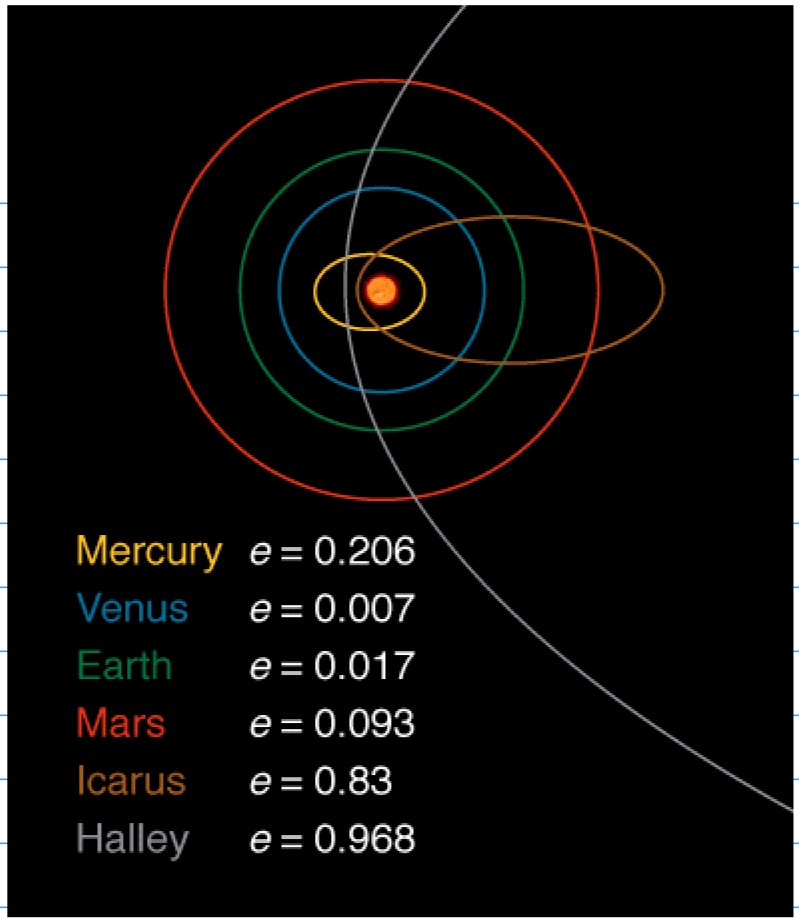


Drawing an **ellipse**: loop string around thumb tacks at each **focus** and stretch string tight with a pencil while moving the pencil around the tacks. The Sun is at one focus.

Kepler's first law:

Planets move in elliptical orbits with the Sun at one focus.

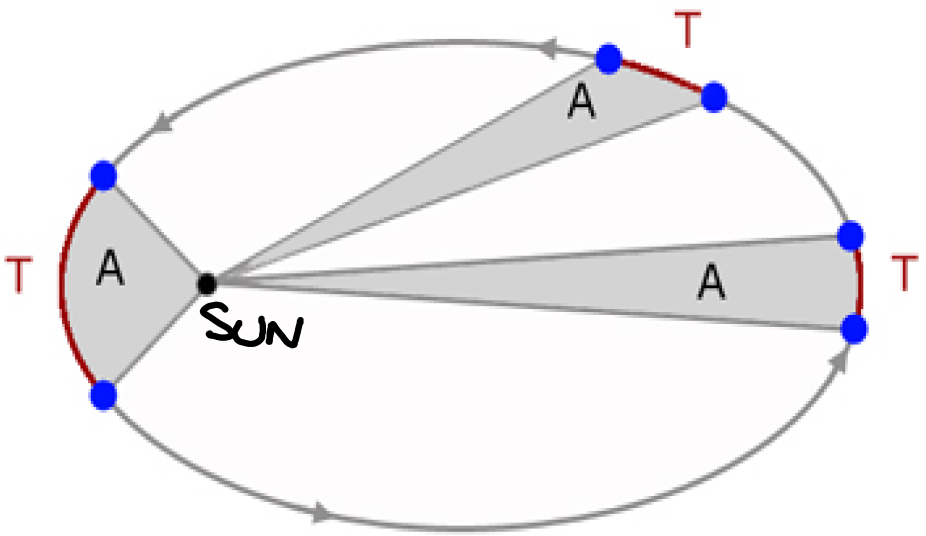
The eccentricity e of an ellipse measures its deviation from circle:



$$e = \frac{\text{FOCUS-CENTER DISTANCE}}{\text{SEMI-MAJOR AXIS}}$$

$e = 0$ GIVES A CIRCLE

KEPLER'S SECOND LAW: THE ORBITAL SPEED OF A PLANET VARIES SO THAT THE LINE JOINING THE PLANET AND THE SUN SWEEPS OVER EQUAL AREAS IN EQUAL TIME INTERVALS.

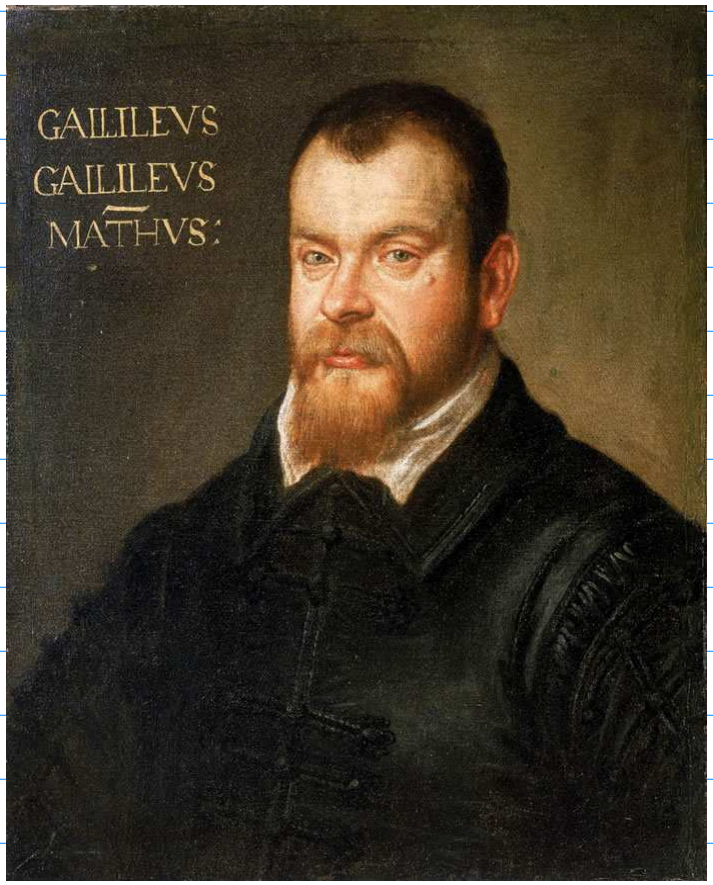


THUS THE CLOSER IS THE PLANET TO THE SUN, THE FASTER IT MOVES.

KEPLER'S THIRD LAW: FOR ALL PLANETS

$$\frac{a^3}{P^2} = 1$$

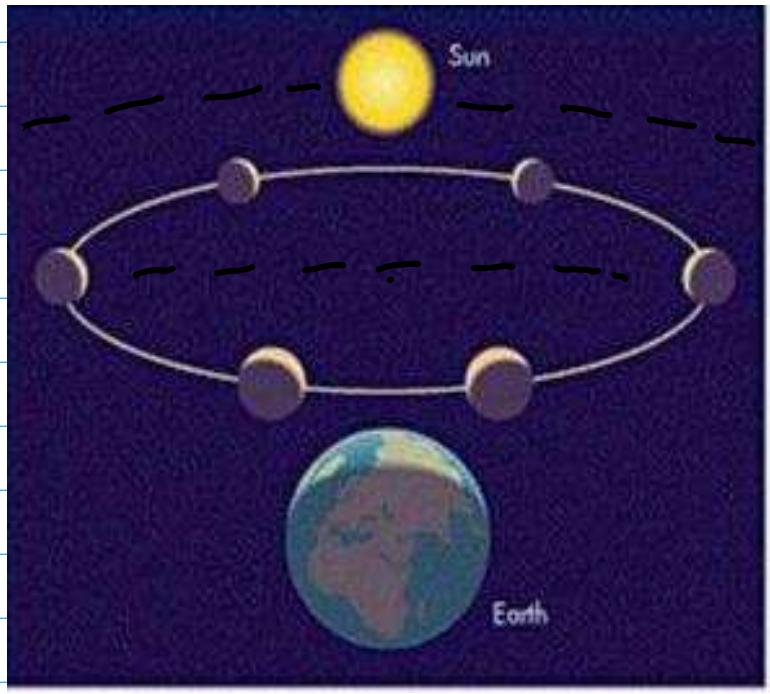
- a: SEMI-MAJOR AXIS (IN AU)
- P: ORBITAL PERIOD (IN YEARS)

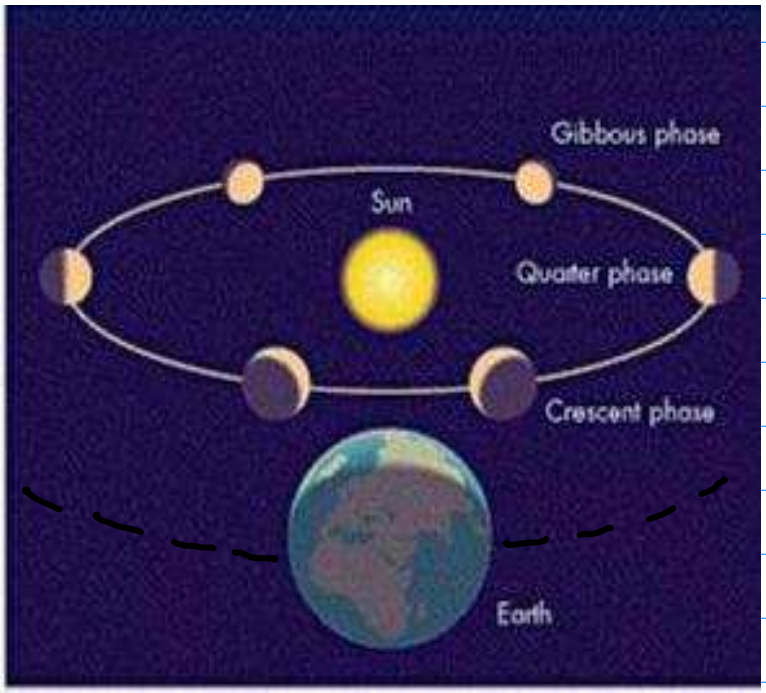


GALILEO GALILEI (1564-1642) IS THE CREATOR OF THE MODERN SCIENTIFIC METHOD: HE BUILT A TELESCOPE (APPARATUS), TURNED IT TO THE SKY (DID THE OBSERVATION/MEASUREMENT) AND REPORTED HIS FINDINGS IN THE STARRY MESSENGER (PUBLISHED THE RESULTS).

HIS MOST IMPORTANT ASTRONOMICAL DISCOVERIES WERE:

1) HE FOUND THAT VENUS SHOWS ALL THE PHASES JUST LIKE THE MOON:



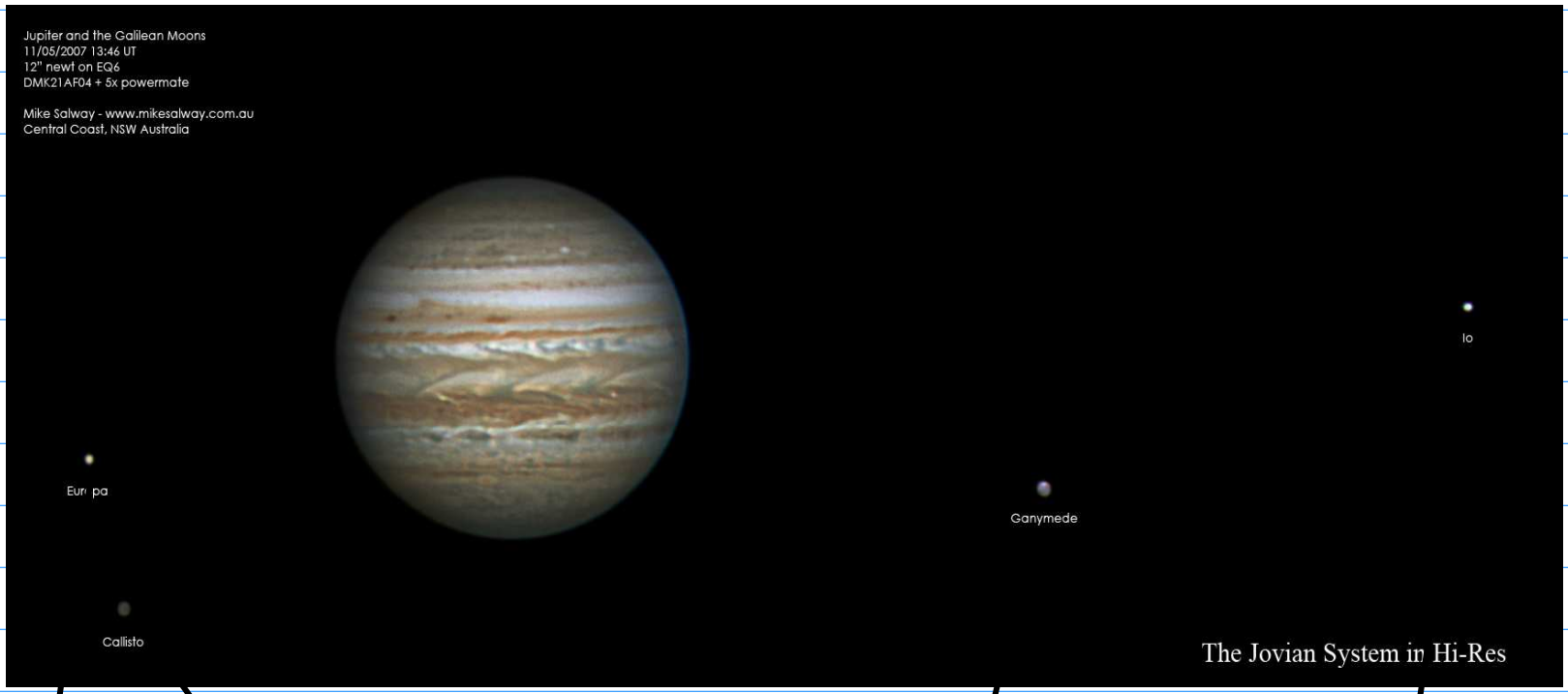


THE GEOCENTRIC MODEL: ONLY THE CRESCENT PHASES WOULD BE OBSERVED

THE HELIOCENTRIC MODEL: ALL PHASES (EXCEPT FOR FULL), INCLUDING QUARTER AND GIBBOUS PHASES WOULD BE OBSERVED

THIS OBSERVATION WAS THE PROOF THAT THE HELIOCENTRIC MODEL WAS THE CORRECT MODEL.

2) HE OBSERVED THE FOUR BIGGEST, AND THUS THE BRIGHTEST, SATELLITES OF JUPITER WHICH ARE NOW NAMED AFTER HIM AS GALILEAN SATELLITES



CALLISTO

EUROPA

GANYMEDE

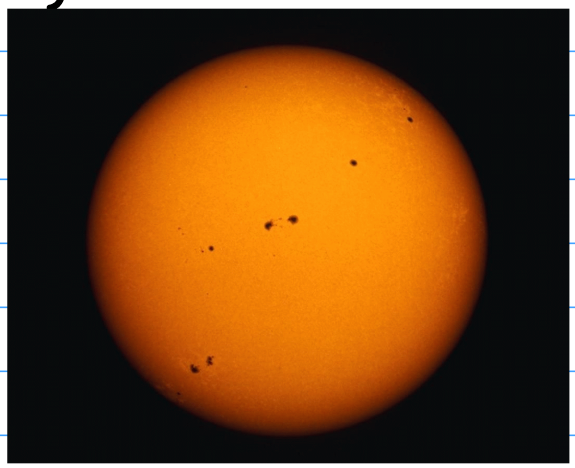
Io

THEREFORE THE EARTH IS NOT THE ONLY BODY AROUND WHICH OTHER BODIES REVOLVE AS POSTULATED BY ARISTOTLE.

3) GALILEO DISCOVERED THE CRATERS AND THE "SEAS" (MARIA) ON THE MOON

THUS THE HEAVENLY BODIES ARE NOT PERFECT SPHERES AS CLAIMED BY ARISTOTLE.

4) GALILEO STUDIED THE SUNSPOTS AND BY FOLLOWING THEM ACROSS THE VISIBLE DISK OF THE SUN HE CONCLUDED THAT THE SUN MUST BE ROTATING.



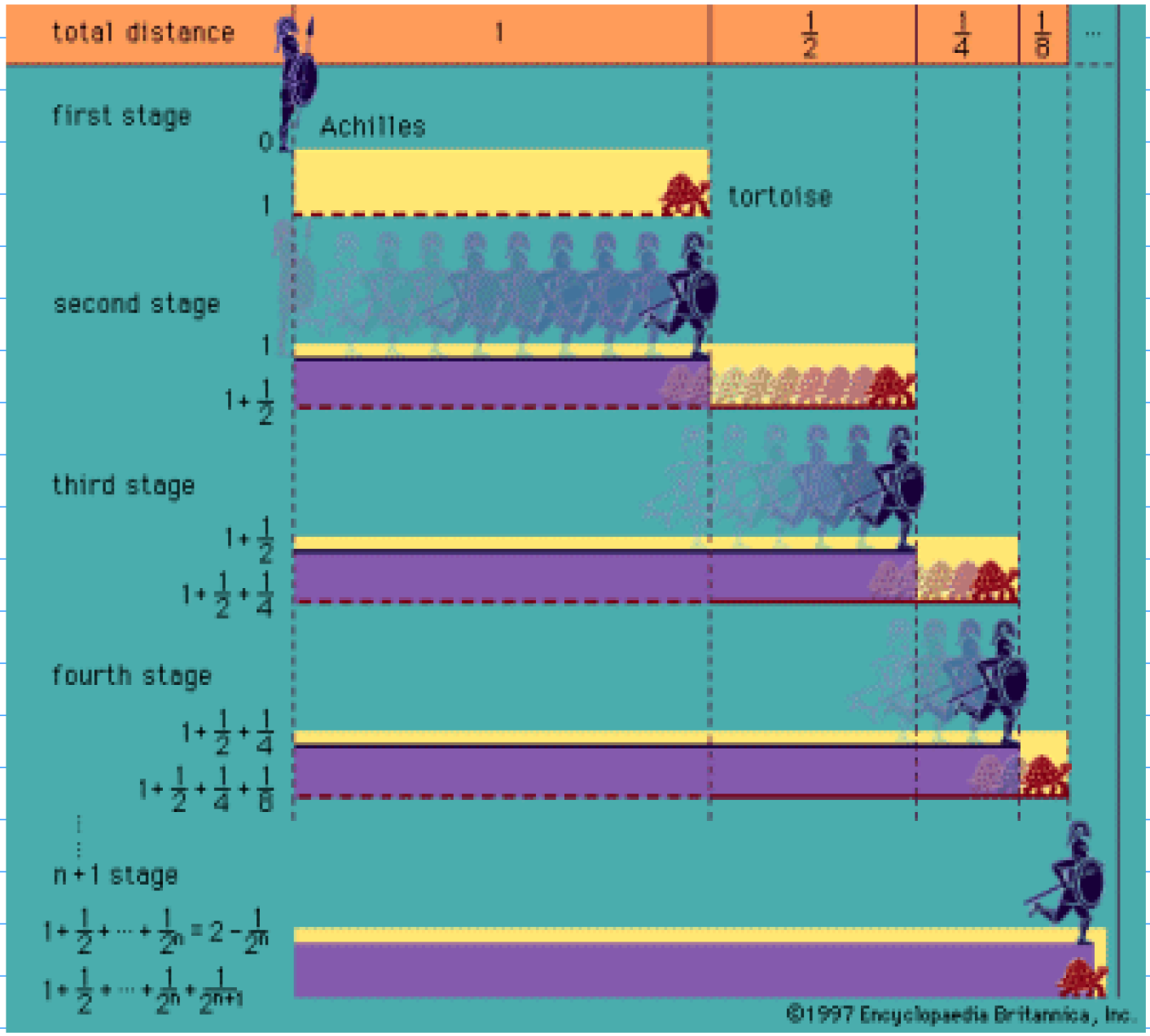
5) HE FOUND THAT WHEN VIEWED THROUGH A TELESCOPE ALL PLANETS HAVE DISK-LIKE APPEARANCE, WHILE THE STARS REMAIN POINT-LIKE EVEN WITH THE LARGEST RESOLUTION. GALILEO CONCLUDED THAT THE STARS MUST BE AT MUCH LARGER DISTANCE FROM US THAN THE PLANETS.

6) 

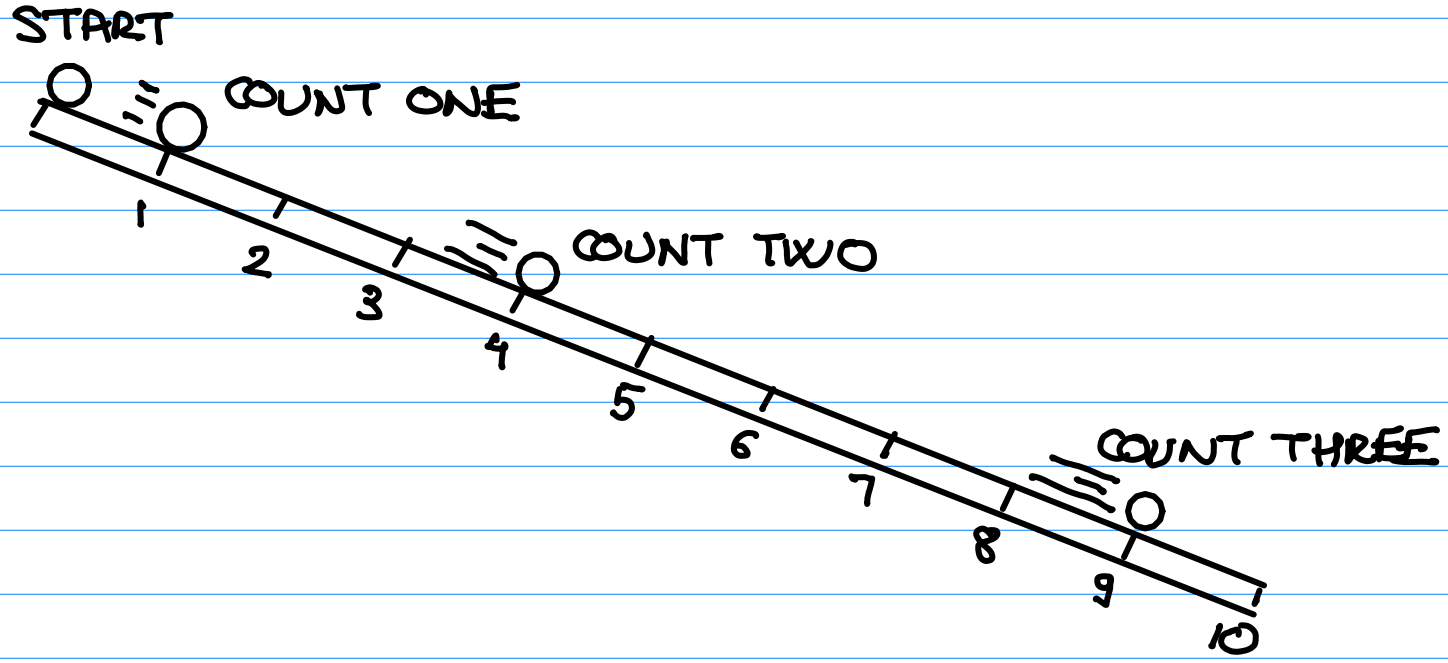
GALILEO FOUND THAT THE DIFFUSE BAND OF LIGHT ACROSS THE SKY, KNOWN AS THE MILKY WAY, ACTUALLY CONSISTS OF MANY STARS TOO FAINT TO BE SEEN BY THE NAKED EYE. HE CONCLUDED THAT THOSE STARS MUST BE MUCH MORE DISTANT THAN THE STARS SEEN WITHOUT A TELESCOPE.

GALILEO ALSO STUDIED THE MOTIONS OF OBJECTS NEAR THE SURFACE OF THE EARTH. UNTIL GALILEO, THE STUDY OF MOTION HAD BEEN A PHILOSOPHICAL IN NATURE:

ZENO'S PARADOX:



INSTEAD, GALILEO DID EXPERIMENTS WITH BODIES IN MOTION:

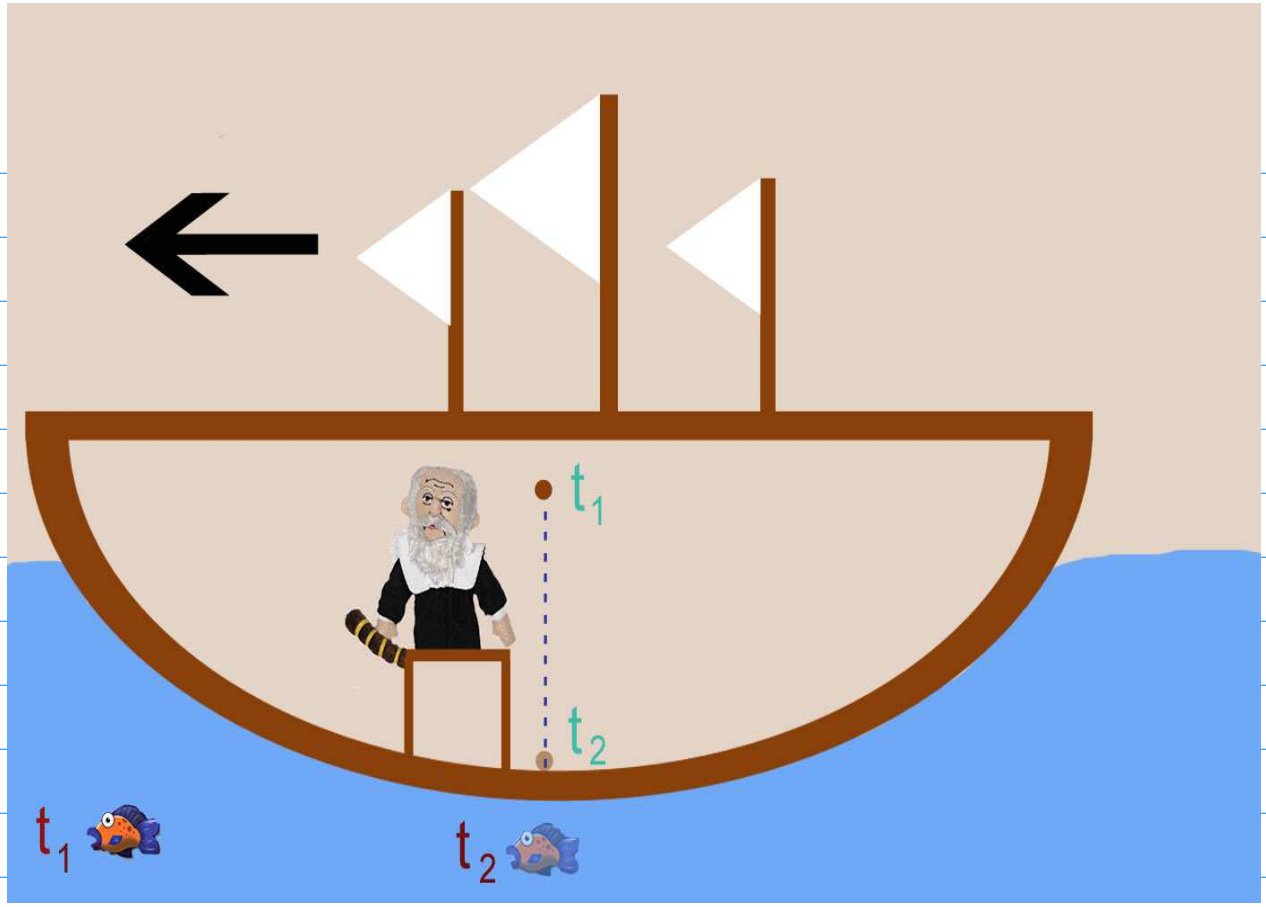


GALILEO MEASURED HOW FAR THE BALL WENT DOWN THE TROUGH IN HOW LONG A TIME AND CONCLUDED THAT

$$\text{DISTANCE TRAVELED} \propto (\text{ELAPSED TIME})^2$$

↑ PROPORTIONAL TO

FROM HIS EXPERIMENTS HE ALSO DEDUCED THE PRINCIPLE OF RELATIVITY:



A PERSON ON THE SHIP COULD NOT TELL IF THE SHIP WAS MOVING OR NOT BY DROPPING AN OBJECT AND NOT LOOKING OUTSIDE.