

HISTORY

CELESTIAL MECHANICS DECOMPOSES INTO TWO PARTS

- FORMAL ASTRONOMY - PHENOMENA APART FROM CAUSES
- DYNAMICAL ASTRONOMY - FUNDAMENTAL PROPERTIES


1. FORMAL ASTRONOMY - VIEWING PHENOMENA WITHOUT CAUSES

ANCIENT ASTRONOMERS

NOTED DIVISIONS OF TIME - DAY, MONTH, YEAR

REMARKABLE ACCURACY - POOR RECORDS

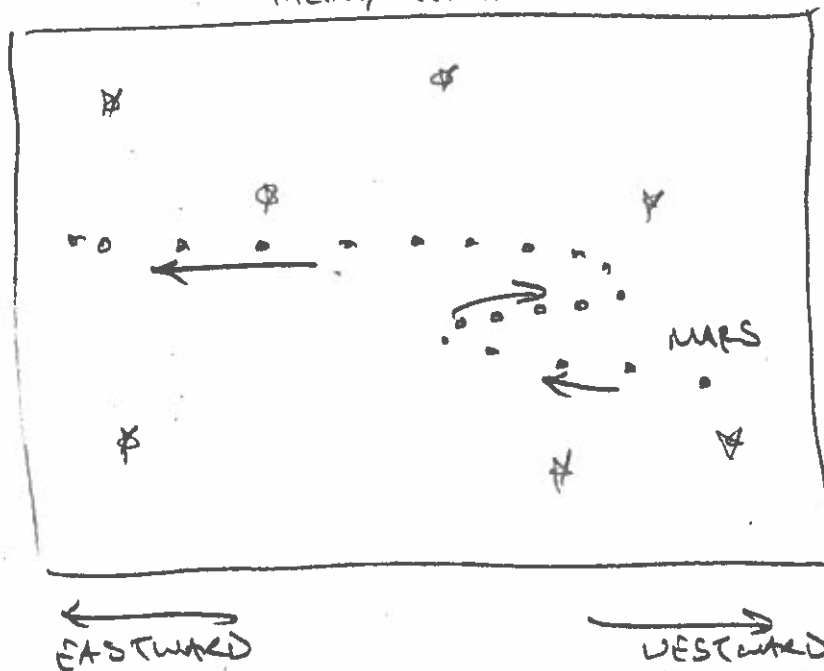
240 BC - CHINESE RECORD HALLEY'S COMET PERHELION


 SOL MERCURIUS VENUS LUNA MARS JUPITER SATURNUS

GREEK ASTRONOMERS - NEXT BIG ADVANCEMENT

- NAME PLANET \Leftrightarrow "WANDERER"
- NEEDED THEORY FOR WHY PLANETS SOMETIMES MOVE RETROGRADE MOTION

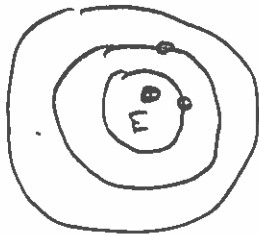
FACING SOUTH



GREEKS LOVED CIRCLES - ASSUMED ALL CELESTIAL BODIES MOVED ON CIRCLES

→ UNIFORM CIRCULAR MOTION - OR COMPOS OF UNIFORM CIRCULAR MOTION

ARISTOTLE
CONCENTRIC SPHERES



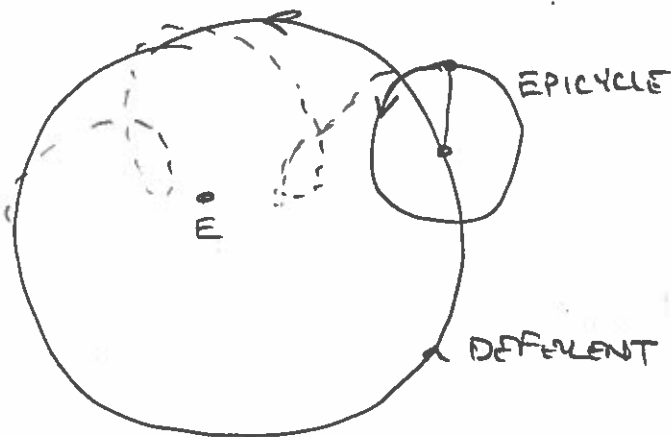
100 - 170 AD

→ DOES NOT PRODUCE OBSERVED MOTION → RETROGRADE

310 - 250 BC

ARISTARCHUS - SUGGESTED A HELIOCENTRIC THEORY - PLANETS ON CIRCLES WITH SUN @ CENTRAL → DOESN'T QUITE MATCH EITHER 15° ERROR

PTOLEMY - THEORY OF EPICYCLES - STILL CLINGING TO CIRCULAR MOTION IDEA

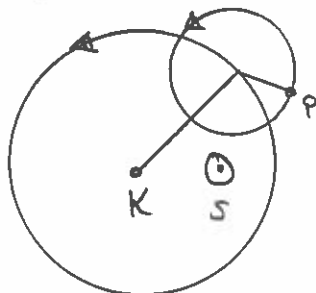


- VERY COMPLICATED MODEL - BUT VERY ACCURATE → 1° ERROR

- EPICYCLES ON EPICYCLES
CIRCULAR MOTION STILL THE WRONG ASSUMPTION!

NICOLAUS COPERNICUS - 1473 - 1543

- HELIOCENTRIC THEORY - STILL OBSESSED WITH CIRCULAR MOTION
- PLANETS ORBIT OFF-CENTER POINT



- SUN CENTERED BUT STILL USES EPICYCLES

TYCHO BRAHE 1546 - 1601

- PAINSTAKING OBSERVER - WANTED TO DISPROVE COPERNICUS
- KEPLER WORKED AS DISCIPLE / ASSISTANT
- THIS IS ALL BEFORE THE TELESCOPE OR EVEN CLOCKS
USED MOTION OF STARS

JOHANN KEPLER 1571 - 1630

- ACCESS TO LOTS OF BRAHE DATA
- WILLING TO FACE MOUNTAIN OF CALCULATION
(NONLINEAR PROBLEM, NO COMPUTER / ASSISTANT)
- RE-EVALUATED INITIAL ASSUMPTION (CIRCLES)

KEPLER'S LAWS OF PLANETARY MOTION 38 YRS OLD

1609 1. THE ORBIT OF EACH PLANET IS AN ELLIPSE WITH
SUN AT A FOCUS

1609 2. THE LINE JOINING THE PLANET TO THE SUN
SWEEPS OUT EQUAL AREAS IN EQUAL TIMES. \rightarrow CALCULUS

1619 3. THE SQUARE OF THE PERIOD OF A PLANET IS
PROPORTIONAL TO THE CUBE OF ITS MEAN DISTANCE
FROM THE SUN.

- ONLY A DESCRIPTION. NOT AN EXPLANATION

\rightarrow LATER NEWTON SHOWS WHY THESE ARE TRUE

- LUCKILY PLANETS ALL ORBIT \approx SINGLE PLANE.

GALILEO GALILEI (1546-1642)

- SUPPORTS HELIOCENTRIC THEORY
- APPLIED THE TELESCOPE TO OBSERVATIONS
- DISCOVERS 4 MOONS OF JUPITER
- FIRST STARTS CONNECTING OBSERVATIONS WITH CAUSES

2. DYNAMICAL ASTRONOMY - CONNECT OBSERVATIONS WITH CAUSES

ARCHIMEDES OF SYRACUSE 287-212

GREATEST MATHEMATICIAN OF HIS AGE

PRINCIPLES OF THE LEVER + THE CENTER OF MASS

LEONARDO DA VINCI 1452-1519

- PAINTER + INVENTOR
- THOROUGHLY UNDERSTOOD MECHANICS - IMPROVED THE WORK OF ARCHIMEDES

SIMON STEVINUS 1548-1620

PUBLISHED MATHEMATICS, HYDRAULICS, MECHANICS

GALILEO

- FIRST ADVANCES IN KINETICS
- ASSUMED A BODY REQUIRED FORCE TO REMAIN IN MOTION
BODY POSSES POSITION RATHER THAN STATE OF MOTION
- FOUNDER OF DYNAMICS

LSN 1
CHRISTIAN HUYGENS (1629-1695) AFTER KEPLER

- PROPOSED THAT MOTION OF PLANETS REQUIRES A FORCE RADIIALLY INWARD $F = \frac{mv^2}{r}$ ← CIRCULAR MOTION BUT WE USE ELLIPSES
- LIKE A STONE WHIRLED AROUND IN A STRING ↓

ISAAC NEWTON 1642-1727

WHAT IS THE ACTUAL FORCE

- COMPLETE FORMULATION OF MECHANICS

1665-1666 - CALCULUS, LIGHT, UNIVERSAL GRAVITATION

1687 - PRINCIPIA

THREE LAWS OF MOTION - EXPLAINS GALILEO'S EXPERIMENTS

1. BODIES CONTINUE IN REST OR UNIFORM MOTION UNLESS ACTED UPON BY A FORCE
2. RATE OF CHANGE OF MOMENTUM IS PROPORTIONAL TO FORCE
3. EVERY ACTION IS OPPOSED BY AN EQUAL / OPPOSITE REACTION

→ USED LAWS OF MOTION TO EXPLAIN KEPLER'S LAWS

$$F = \frac{GMm}{r^2} \rightarrow N\text{-BODY, VS. } 2\text{-BODY}$$

NEWTON CHANGED THE APPROACH

PRE

- EVERY ORBIT APPROX. BY CIRCULAR MOTION COMBOS
- NO IDEA THAT MOTION WAS BASED ON MUTUAL INTERACTION → GRAVITY

POST

- ORBITS COULD BE EXACTLY CALCULATED (IN PRINCIPLE)
- MATHEMATICAL MODEL TO PREDICT OBSERVATIONS



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INTRODUCTION TO TIME

- TIME IS A FUNDAMENTAL DIMENSION IN SCIENCE
- VERY IMPORTANT IN ASTRODYNAMICS BC OBJECTS MOVE VERY QUICKLY - $8 \text{ km/sec} \pm$
- REQUIREMENTS
 - REPEATABLE/PRECISE TIME INTERVAL BASED ON PHYSICAL PHENOMENA
 - FUNDAMENTAL EPOCH

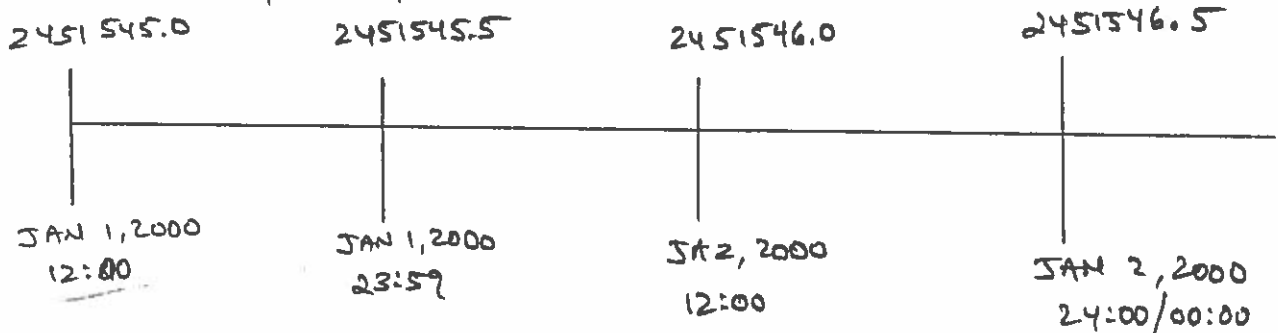
EPOCH - PRECISE MOMENT OF A PARTICULAR EVENT

JULIAN DATE

- INTERVAL OF TIME IN DAYS SINCE
1 JAN 4713 BC 12:00 NOON
- - JOSEPH SCALIGER (1582) COMBINED THREE KNOWN CYCLES
 - SOLAR CYCLE (28 YRS)
 - METONIC CYCLE (19 YRS)
 - ROMAN INDICATION (15 YR)

} JULIAN PERIOD
7980 JULIAN YRS
(365.25) day
- COMMON POINT OF CYCLES IS 4713 BC
- NAMED AFTER HIS FATHER NOT JULIUS CAESAR
- DAY BEGINS AT NOON - ASTRONOMERS MAKE OBS.

DURING NIGHT ON A SINGLE DAY



- JULIAN DAY WILL BE BIG NUMBERS - PRECISION !

- MODIFIED JULIAN DATE

$$MJD = JD - 2400000.5$$

- MANY FORMULAS GIVEN IN JD, ALSO THIS IS ONE CONSISTENT NUMBER RATHER THAN MANY

- USE astro.time . date2jd (yr, mo, day, hr, min, sec)
 . jd2date (JD)

TO CONVERT.